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DMA ORBIT DETERMINATION  
OF THE  
NAVY NAVIGATION SATELLITE SYSTEM  
1987

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ROBERT J. JONES



DEFENSE MAPPING AGENCY  
WASHINGTON, DC 20305-3000

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## INTRODUCTION

The Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC) performs precise orbit computations for Navy Navigation Satellite System (NNSS) satellites, also called TRANSIT, using Doppler observations collected by a worldwide network of stations. Equipment at these sites is configured around either a Tranet II or a Magnavox 1502 DS receiver. Table 1 lists the current stations while Figure 1 shows the tracking network configuration. Recorded Doppler counts, surface weather measurements, and other appropriate data are transmitted daily via satellite communications or over other telecommunication links to DMAHTC for processing, time corrections and orbit determination. There are two classes of NNSS satellites - the "Oscar" and the "Nova". The Nova satellites represent the latest generation of TRANSIT satellites. For Nova satellite 30480 and Oscar satellites 30110, 30130, 30200, 30240 and 30300, data were processed in two-day fits. For Nova satellite 30500, data were processed in one-day fits. Table 2 and Figure 2 provide additional information on these satellites.

TABLE 1: 1987 TRACKING STATIONS

1502 DS Stations

<u>Station Number</u>	<u>Station Location</u>
30690	Herndon, Virginia
35000	Ascension Island
35004	St. Helena Island
35006	Dhekelia, Cyprus
35010	Diego Garcia Island
35011	Cambridge Bay, Canada
35012	Bahrain, Persian Gulf
35013	Asuncion, Paraguay
35015	Wichita Falls, Texas
35017	Sioux City, Iowa
35018	Shemya, Alaska
35021	Las Cruces, New Mexico
35022	Quito, Ecuador
35024	Sigonella, Italy
35025	Santiago, Chile
35026	Kinshasa, Zaire
35027	Aurora, Colorado
35028	Bangkok, Thailand
35029	Rapid City, South Dakota
35036	Idaho Falls, Idaho
35037	Flagstaff, Arizona
35038	NAS Fallon, Nevada
35039	NAS Meridian, Mississippi
35047	Grissom AFB, Indiana
35048	Hickam AFB, Hawaii

Tranet II Stations

545	Smithfield, Australia
547	Brussels, Belgium
548	Mizusawa, Japan
550	Herndon, Virginia
552	Las Cruces, New Mexico
553	Guam (U.S.)
554	Pretoria, South Africa
555	Sao Jose, Brazil
556	Anchorage, Alaska
557	Thule, Greenland
558	Mahe, Seychelles
559	San Miguel, Philippines
560	Tafuna, American Samoa
561	Austin, Texas
562	McMurdo, Antarctica
563	Calgary, Canada
564	Ottawa, Canada
565	Wettzell, West Germany

567  
568  
569  
570  
590  
591

Kerguelen Island  
Papeete, Tahiti  
Toulouse, France  
Hermitage, United Kingdom  
San Fernando, Spain  
Kourou, French Guiana

FIGURE 1: 1987 TRACKING NETWORK  
**THE WORLD**

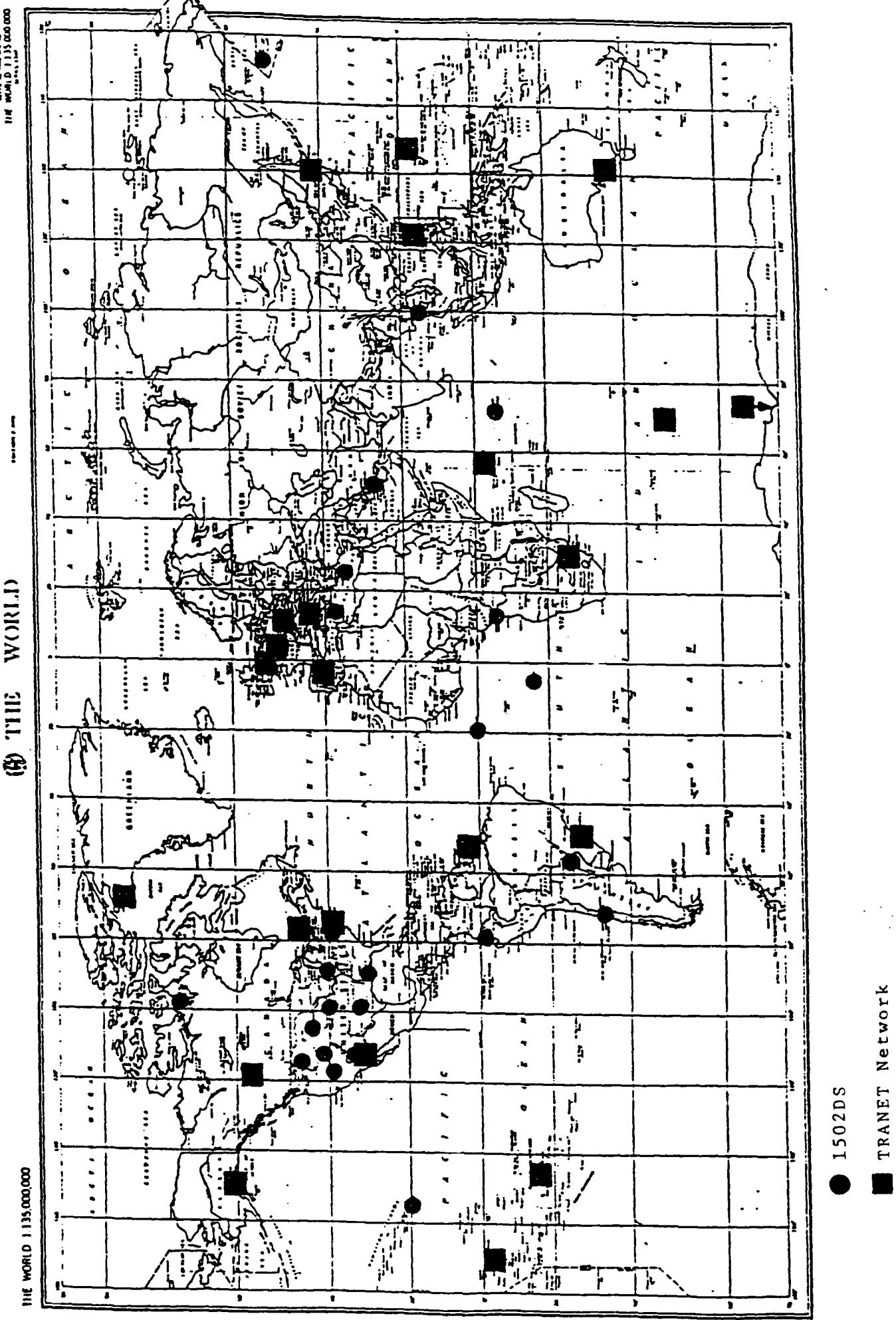
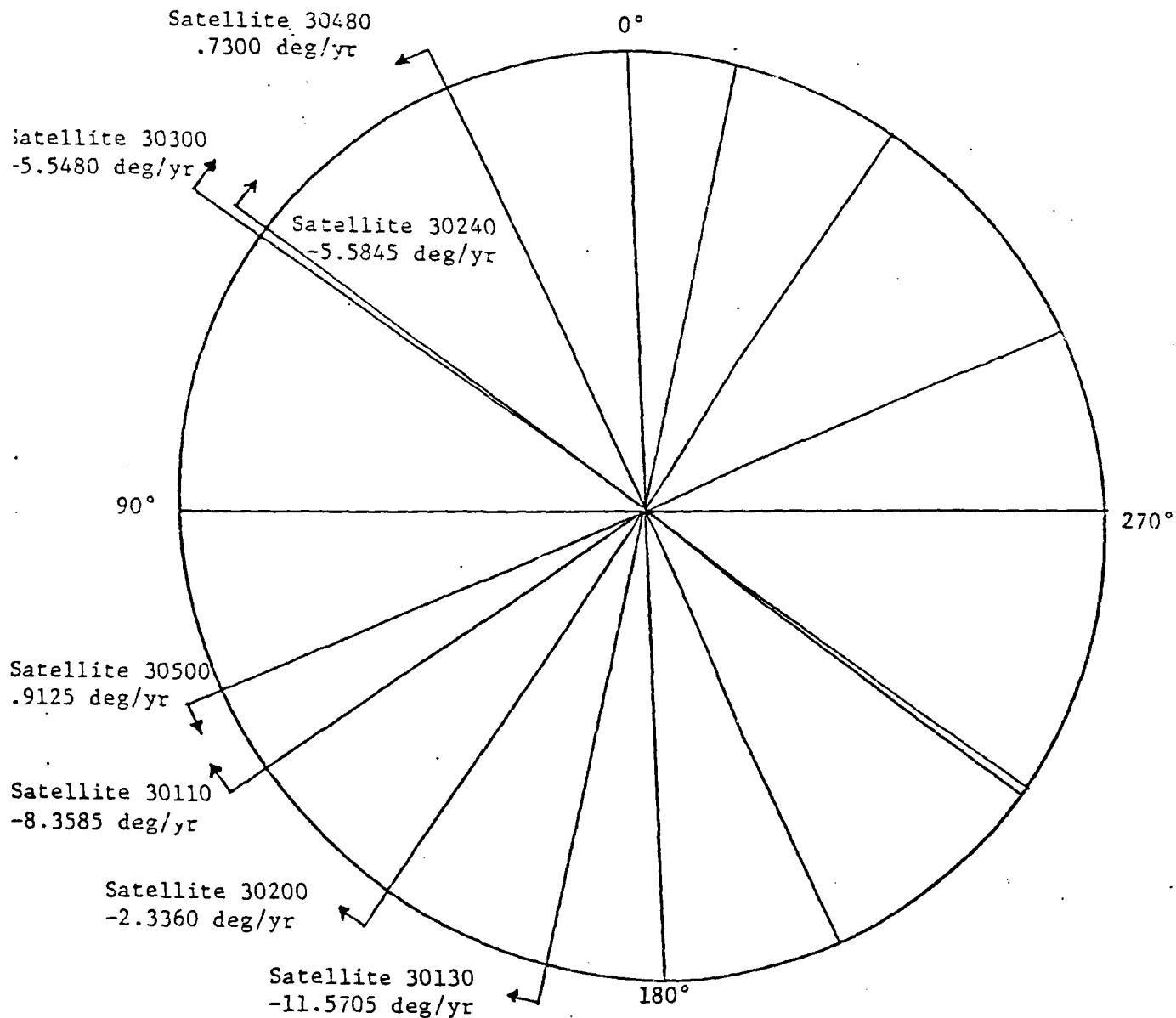


TABLE 2: STATUS REPORT ON USABLE SATELLITES AS OF DECEMBER 1987

<u>TRANSIT Satellite Number</u>	<u>Launch Date</u>	<u>Status</u>
30110	28 Oct 1987	Operational 121 months
30130	18 May 1967	Operational 246 months
30110	29 Oct 1973	Operational 169 months
30240	3 Aug 1985	Operational 28 months
30300	3 Aug 1985	Operational 28 months
30480	15 May 1981	Operational 76 months
30500	12 Oct 1984	Operational 36 months

These satellites are controlled by the Navy Astronautics Group (NAG) headquartered at Point Mugu, California.

FIGURE 2: TRANSIT ORIENTATION CHART



Right Ascension Epoch 87236

### EPHEMERIDES

Orbits for the six TRANSIT satellites were computed in 1987 on a one-day or two-day basis as previously mentioned, using the CELEST orbit determination program. Ephemerides were computed for the days provided in Table 3.

The orbit computation program provides sufficient diagnostic information to judge the overall quality of estimated ephemerides, the stability of satellite and tracking station clocks, and the performance of the tracking network. One quantity computed within the CELEST program, used as a measure of ephemeris quality, is the station navigation solution. After the satellite ephemeris is estimated, each individual pass of Doppler data acquired during the fit span is used to adjust the geodetic coordinates of the tracking station in directions along and perpendicular to the slant range vector to the satellite at its time of closest approach during the pass. These individual two - parameter station adjustments provide a measure of the consistency of the data with the estimated ephemeris. From these station navigation estimates, a weighted root mean square (RWS) is computed, where the weighting factor for each pass is chosen as the variance of the pass navigation solution.

Table 4 provides the average of the RWS station navigation results for all orbit determinations computed during 1987. These average values, labeled tangential (along - track direction) and radial (slant - range direction), are a measure of the internal consistency of computed ephemerides with the acquired Doppler data.

A measure of orbit repeatability can be obtained by comparing the estimated satellite position at the beginning of each fit span with the estimated satellite position at the end of the previous span. These comparisons are made in the radial, tangential, and normal directions using the satellite position and velocity vectors to define the coordinate system. Averages for these quantities for the year 1987 are found in Table 4 under orbit consistency.

TABLE 3: 1987 TRANSIT EPHEMERIS AVAILABILITY

<u>TRANSIT Satellite Number</u>	<u>Day Number</u>
30110	1-265,267-365
30130	1-365
30200	1-365
30240	189-365
30300	1-259
30480	1-289,295-365
30500	1-365

TABLE 4: SUMMARY OF EPHEMERIS QUALITY

UNITS: METERS

Satellite 30110				Satellite 30130				Satellite 30200				Satellite 30240			
Tangential	Radial	Normal	Tangential	Radial	Normal	Tangential	Radial	Normal	Tangential	Radial	Normal	Normal	Radial	Normal	
Data Consistency	1.8	1.4		1.4	1.3		1.4	1.4		1.0	0.8				
Orbit Consistency	7.7	3.3	1.0	2.6	0.7	1.4	3.6	0.9	1.3	2.5	1.0	0.8			

Satellite 30300				Satellite 30480				Satellite 30500			
Tangential	Radial	Normal	Tangential	Radial	Normal	Tangential	Radial	Normal	Radial	Normal	Normal
Data Consistency	0.8	0.7		0.9	0.7		0.6	0.6			
Orbit Consistency	2.3	0.8	0.8	1.9	0.8	1.3	1.3	0.4	0.4	0.6	

### TIME STABILITY

Time stability for the Navy Navigation Satellite System is maintained through the operations of the Naval Astronautics Group at Point Mugu, California. Time is maintained for Oscar satellites through the deletion of cycle counts generated by a satellite crystal oscillator operating at a frequency slightly above a nominal frequency. Fractional frequency fluctuations are compensated for by estimating oscillator instability and by adjusting cycle counts appropriately. An actual time drift will still occur; however, the time error will be maintained within prescribed limits. For Nova satellites time stability is maintained by varying the frequency of the satellite crystal oscillator. This frequency steering occurs daily, as necessary, for satellite 30500 but is not used on satellite 30480 due to a partial failure of the frequency steering mechanism.

As part of the DMAHTC orbit determination solution, satellite frequency bias and drift are estimated. Frequency bias causes a time drift to occur equal to the ratio of the frequency bias to oscillator base frequency multiplied by the effective time span of the bias. Frequency drift causes a quadratic time error equal to the ratio of the frequency drift to oscillator base frequency multiplied by one - half the square of the effective time span of the drift. The long - term frequency stability for the Navy navigation satellites was calculated using the estimated daily frequency bias from CELEST orbit processing. Since this value is readily available on a one-day or two-day basis, long term trends in frequency stability were obtained. Figures 3 through 7 give the plots of estimated frequency bias for Oscar satellites 30110, 30130, 30200, 30240 and 30300 respectively. Figure 8 gives similar results for Nova satellite 30480.

Based on these data, average annual frequency drifts for each satellite were computed and are given in Table 5.

FIGURE 3: SATELLITE 30110 FREQUENCY ERROR

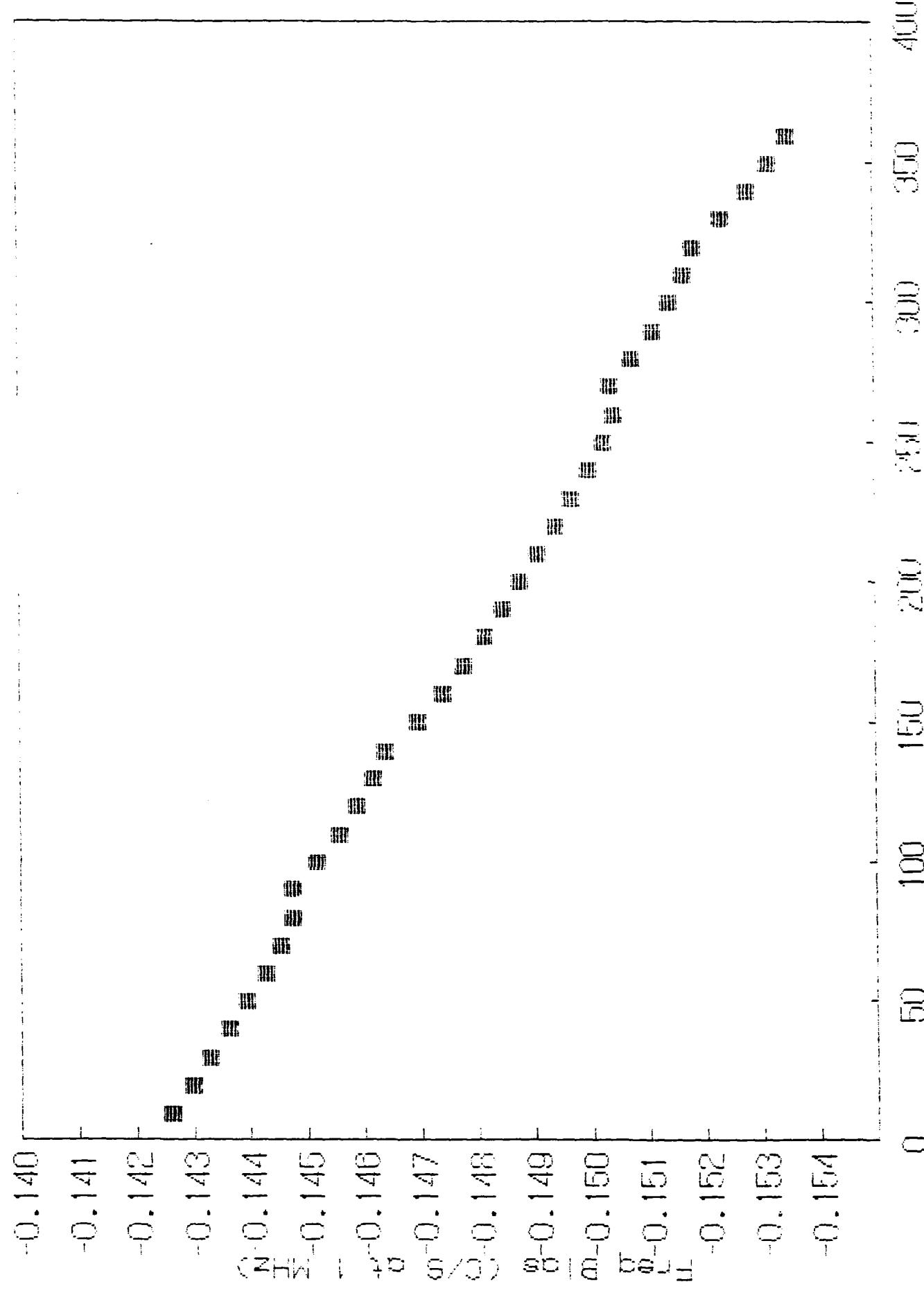


FIGURE 4: SATELLITE 30130 FREQUENCY ERROR

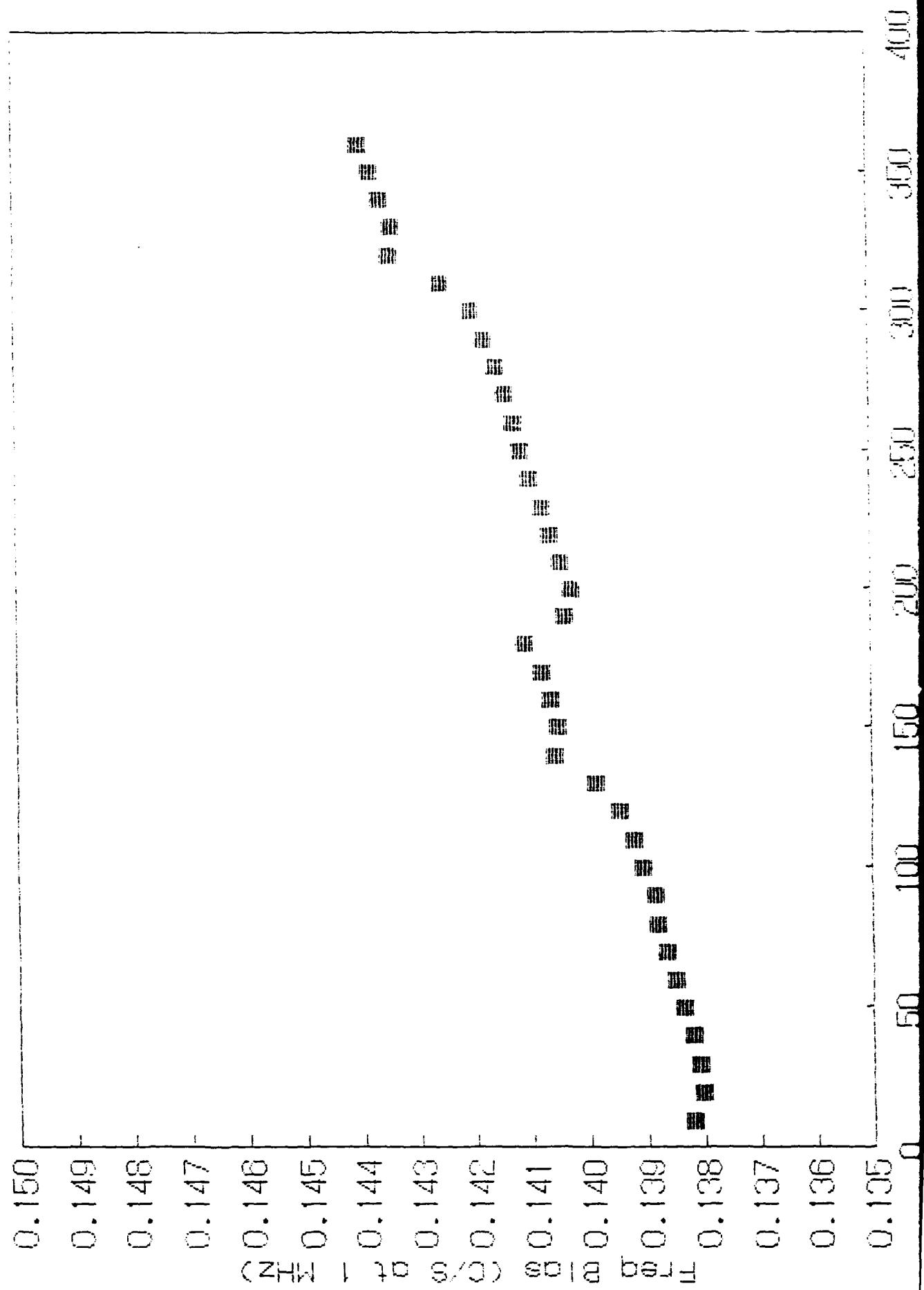


FIGURE 5: SATELLITE 30200 FREQUENCY ERROR

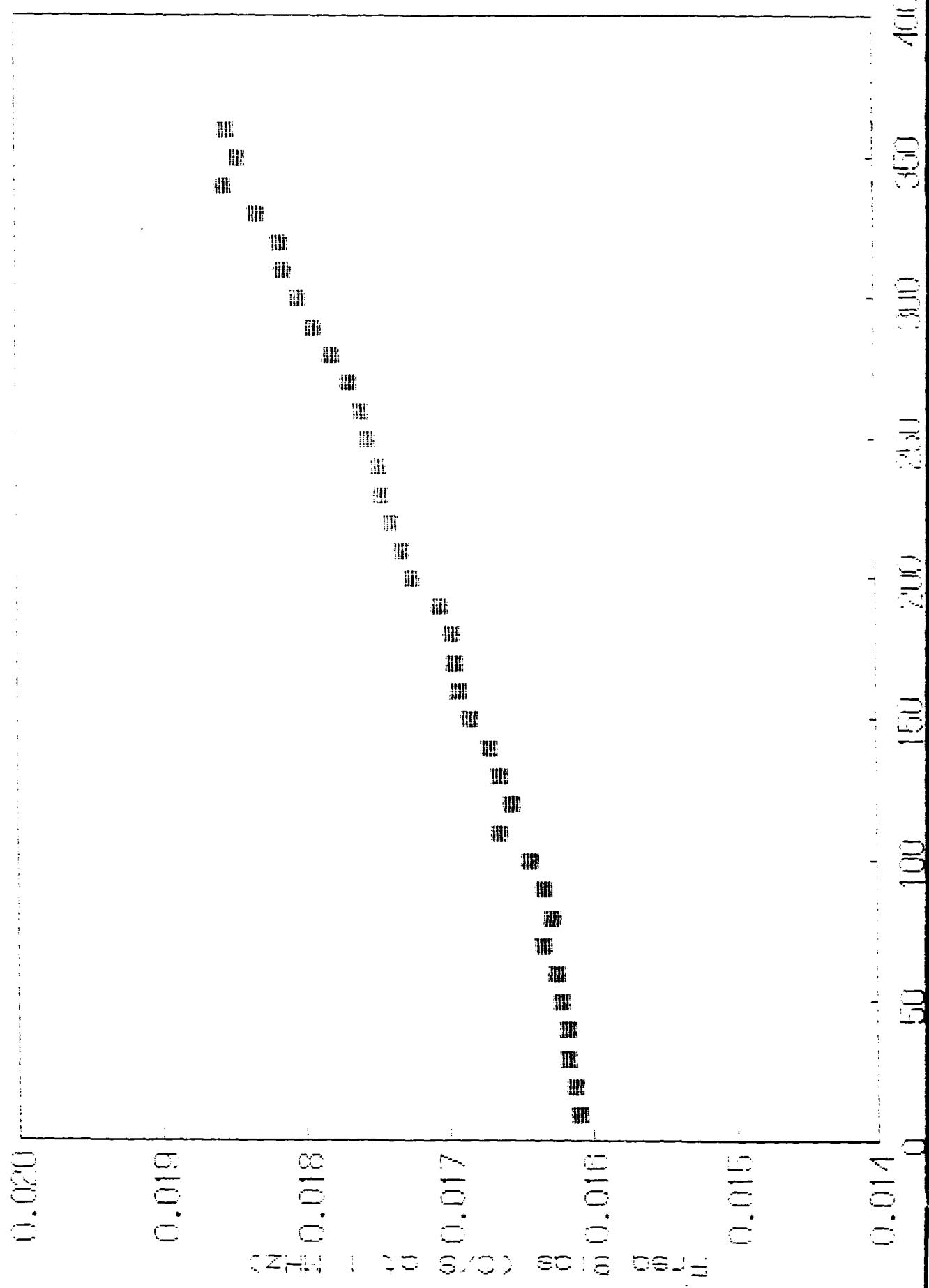


FIGURE 6: SATELLITE 30240 FREQUENCY ERROR

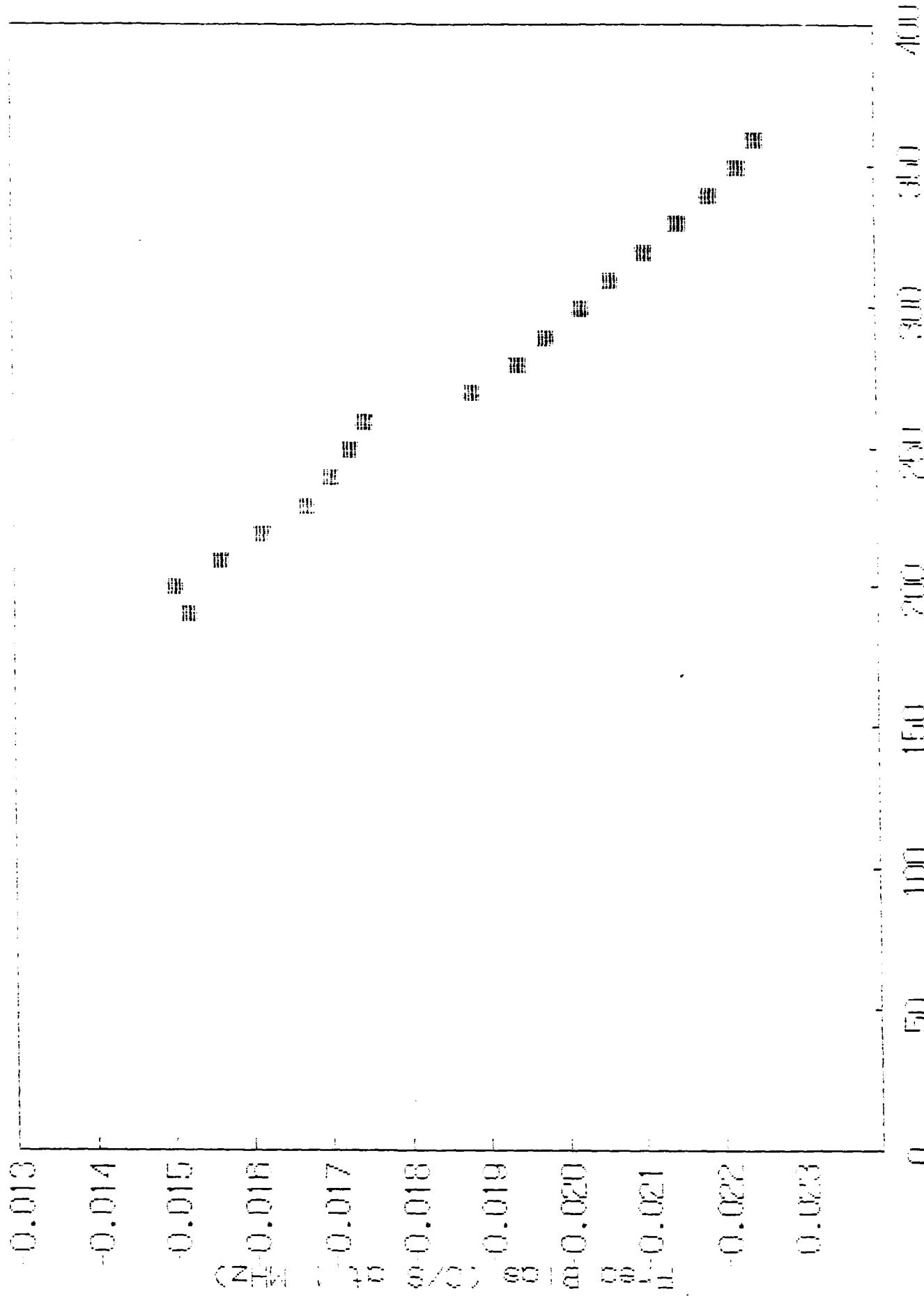


FIGURE 7: SATELLITE 30300 FREQUENCY ERROR

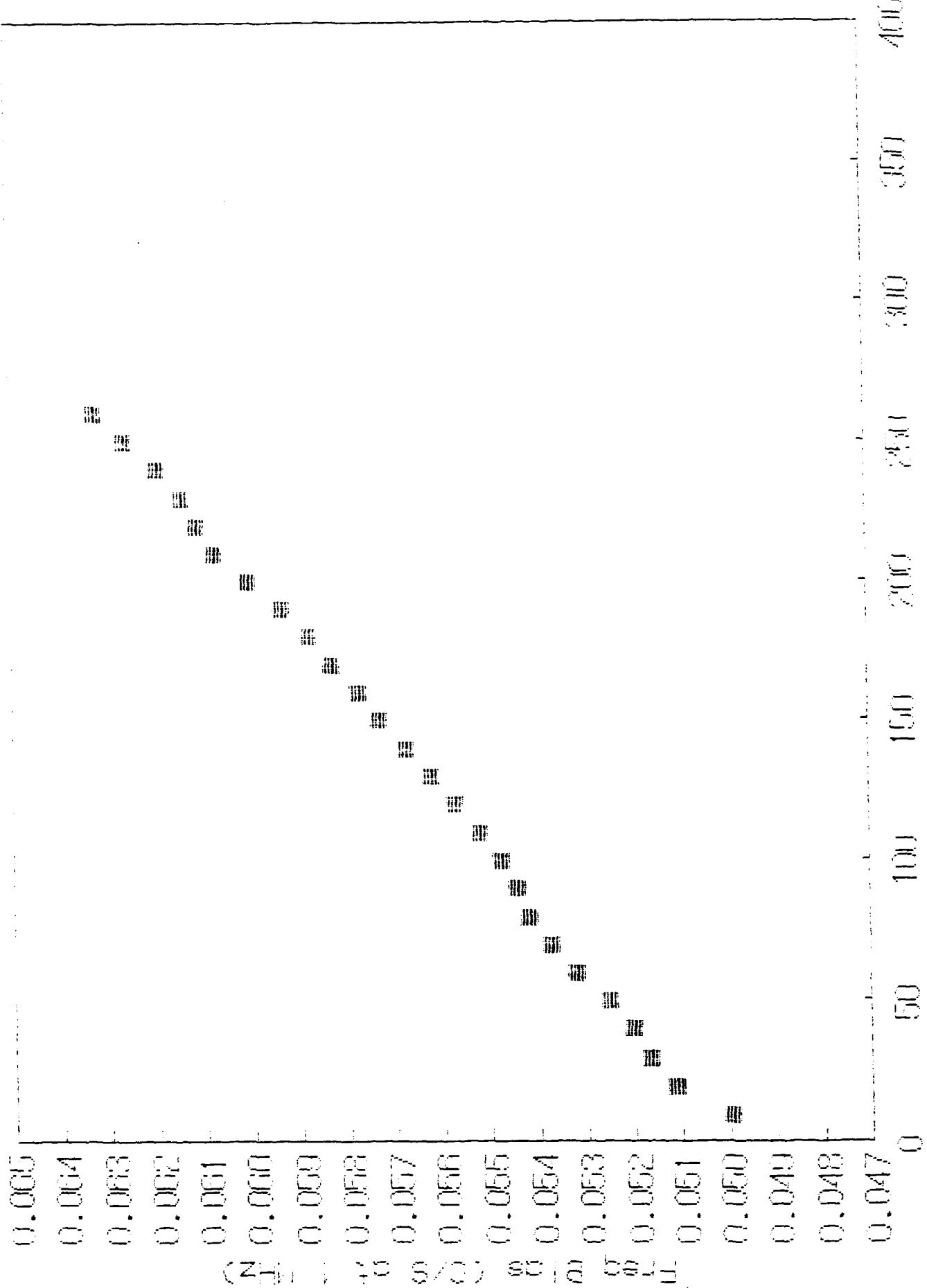


FIGURE 8: SATELLITE 30480 FREQUENCY ERROR

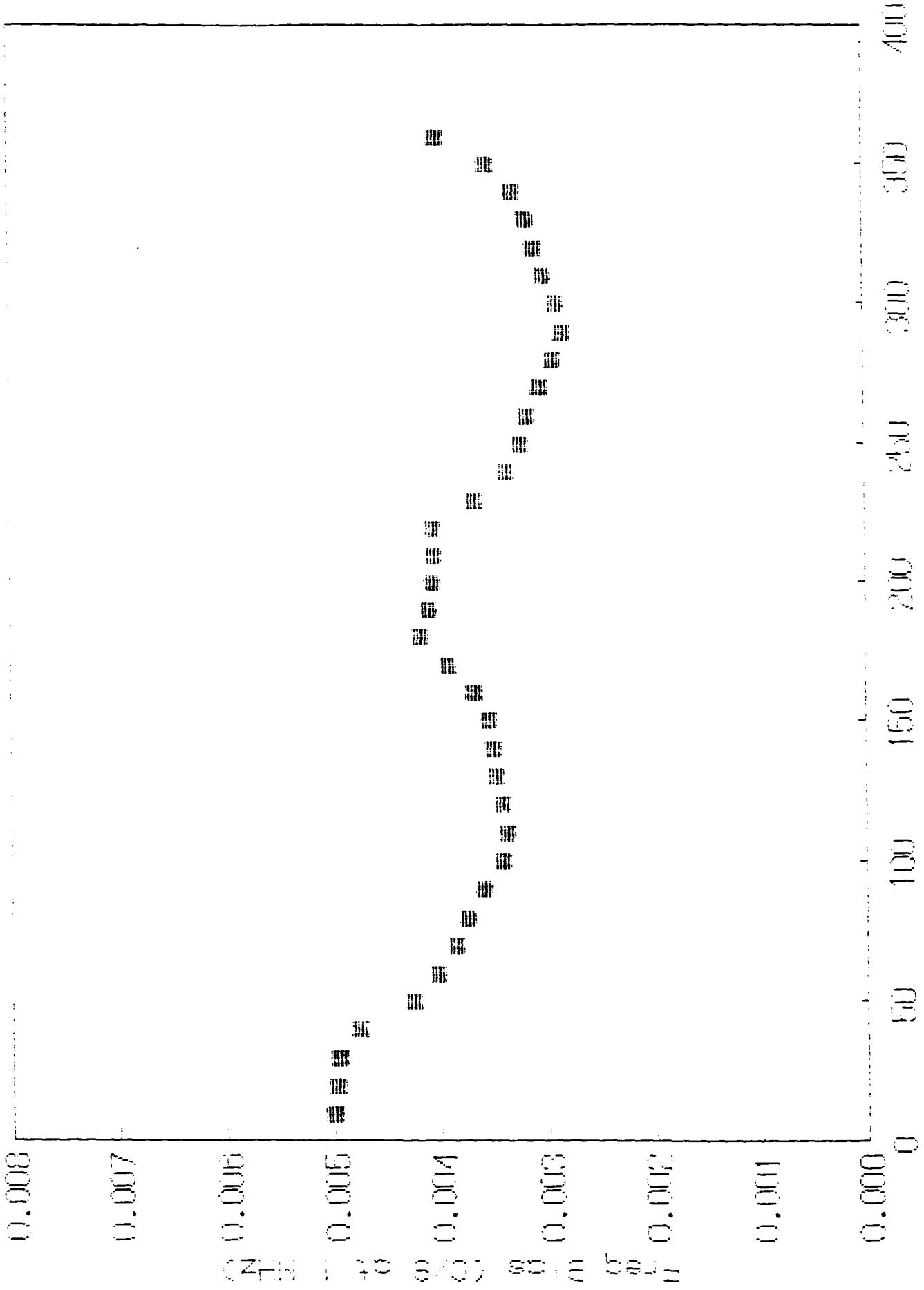


TABLE 5: 1987 MEAN FREQUENCY STABILITY

<u>TRANSIT Satellite Number</u>	<u>Daily Mean Drift *</u>
30110	$\sim 30 \times 10^{-6}$
30130	$13 \times 10^{-6}$
30200	$70 \times 10^{-7}$
30240	$\sim 20 \times 10^{-6}$
30300	$53 \times 10^{-6}$
30480	$\sim 30 \times 10^{-7}$
30500	**

\* Units: Cycles per second per day at 1 MHz

\*\* Stability is maintained by active frequency steering.

### POLAR MOTION

Included among the parameters estimated in the orbit determination program is the position of the Earth's spin axis with respect to the pole of the adopted Defense Mapping Agency WGS-84 terrestrial frame. The scheme used to compute daily pole values is as follows: each satellite for which two-day spans of data are used for orbit determination is designated to have an odd or even starting day number. Consequently, for each day of the year, pole positions are determined using less than seven satellites. The fit span and two-day designator are provided in Table 6 for each satellite. Satellite data processed daily produce pole position estimates on both odd and even days. Figures 9 through 15 are plots of the 1987 DMAHTC Doppler pole position values for each NNSS satellite. Much of the detail of the plot for Nova satellite 30500 is lost due to the density of data points and their scatter. Table 7 is a comparison of Doppler and BIH polar motion values for 1987.

TABLE 6: 1987 POLAR MOTION PROCESSING SCHEME

TRANSIT Satellite Number	Processing Interval (Days)		Designator
	One-Day	Two-Day	
30300	-	1-259	Even
30130	-	1-364	Even
30200	-	1-364	Odd
30240	-	189-364	Odd
30110	-	1-265 267-364	Even
30480	-	1-289 295-365	Odd
30500	1-364	-----	Even, Odd

FIGURE 9:  
SATELLITE 30110  
DOPPLER POLAR MOTION  
RESULTS DURING  
1987

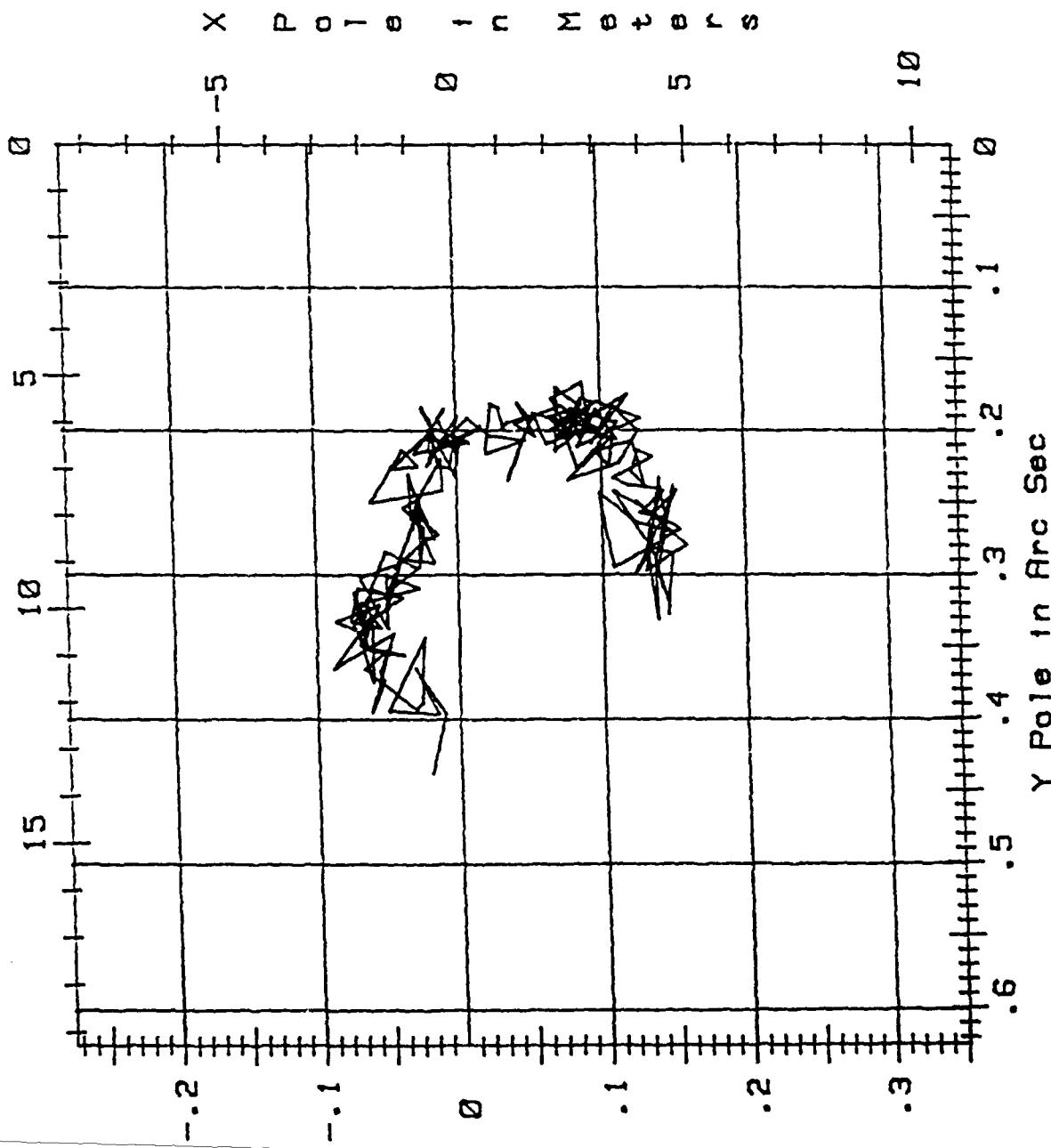


FIGURE 10:  
SATELLITE 30130  
DOPPLER POLAR MOTION  
RESULTS DURING  
1987

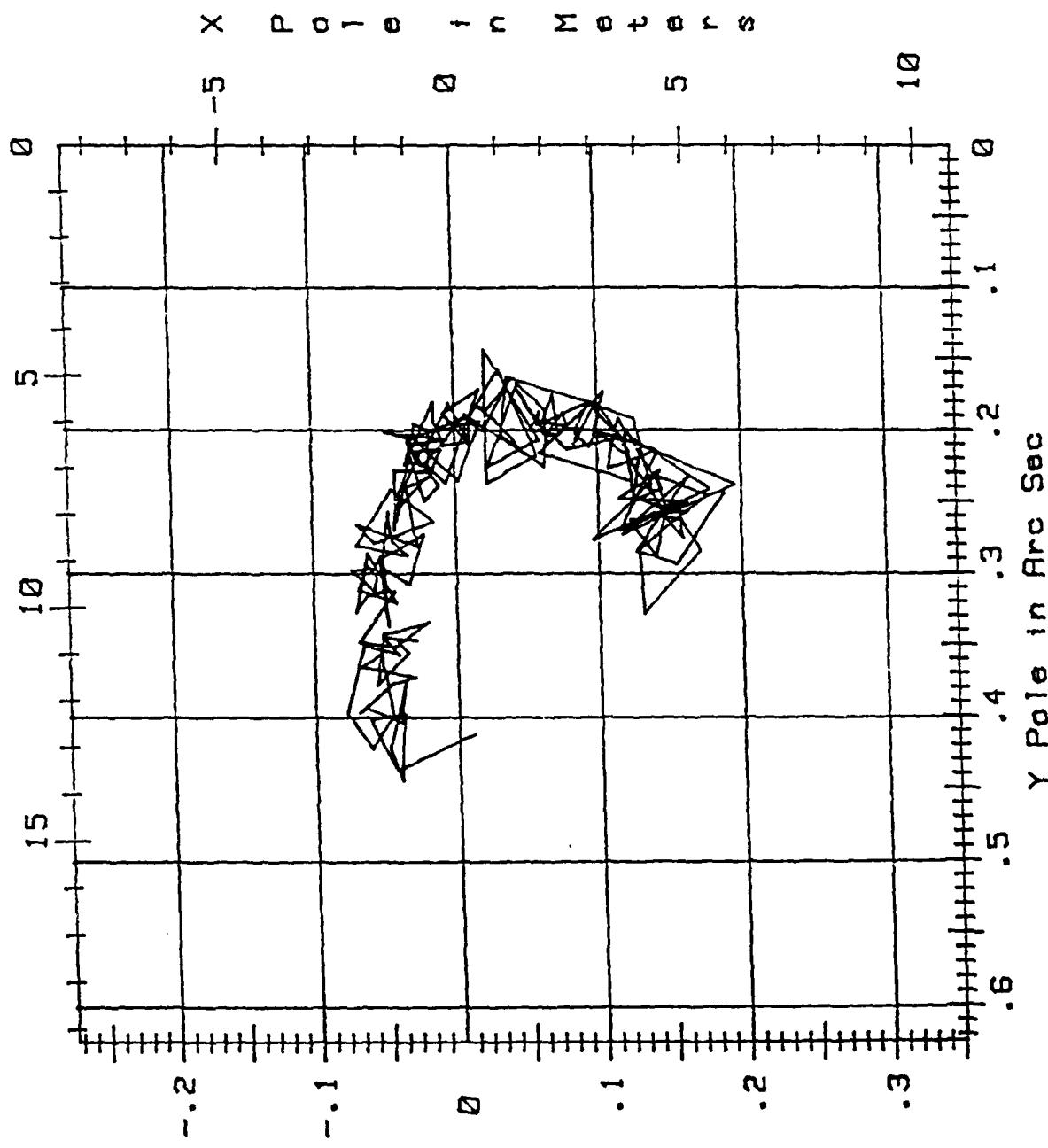


FIGURE 11:  
SATELLITE 30200  
DOPPLER POLAR MOTION  
RESULTS DURING  
1987

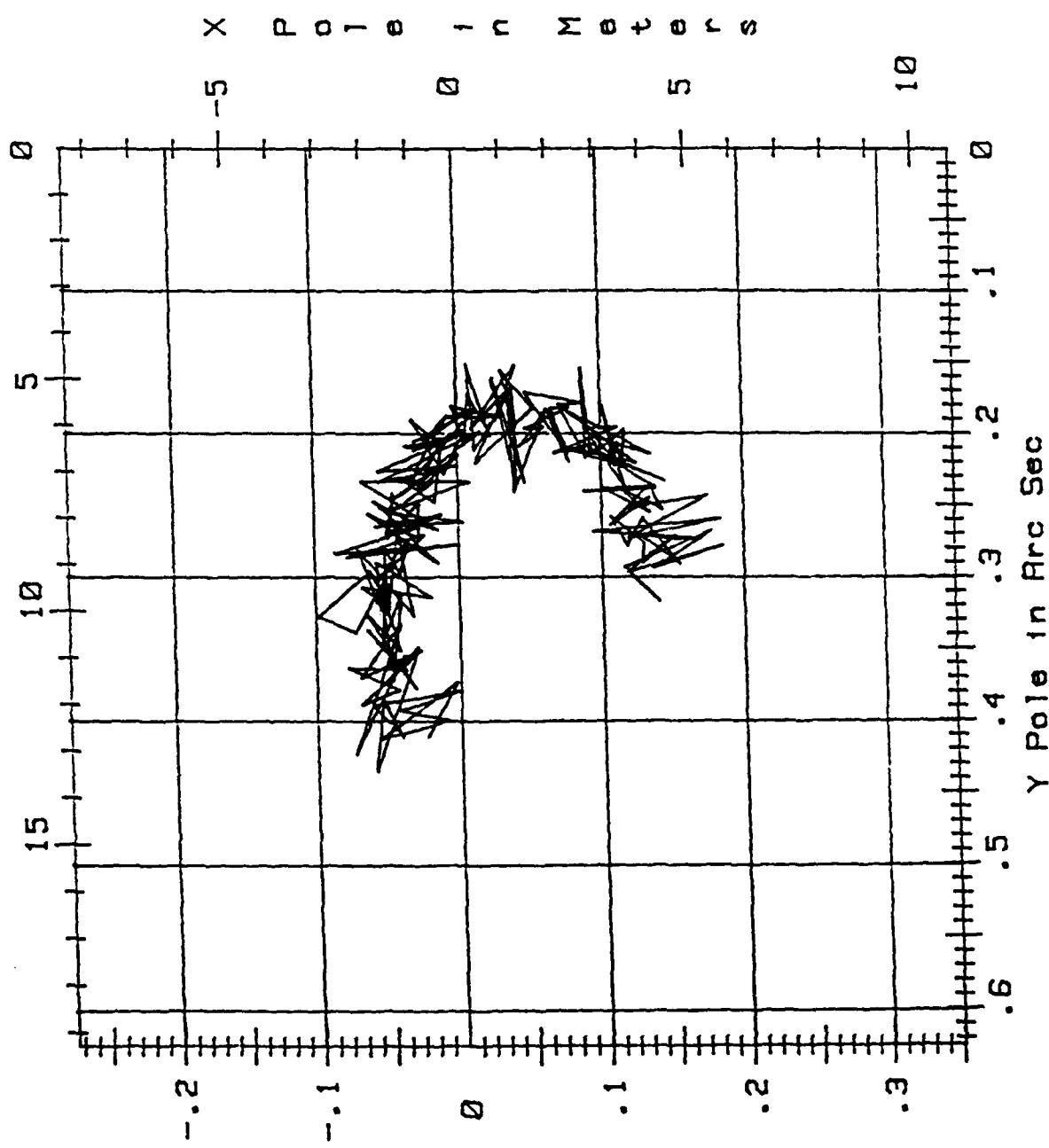


FIGURE 12:  
SATELLITE 30240  
DOPPLER POLAR MOTION  
RESULTS DURING  
1987

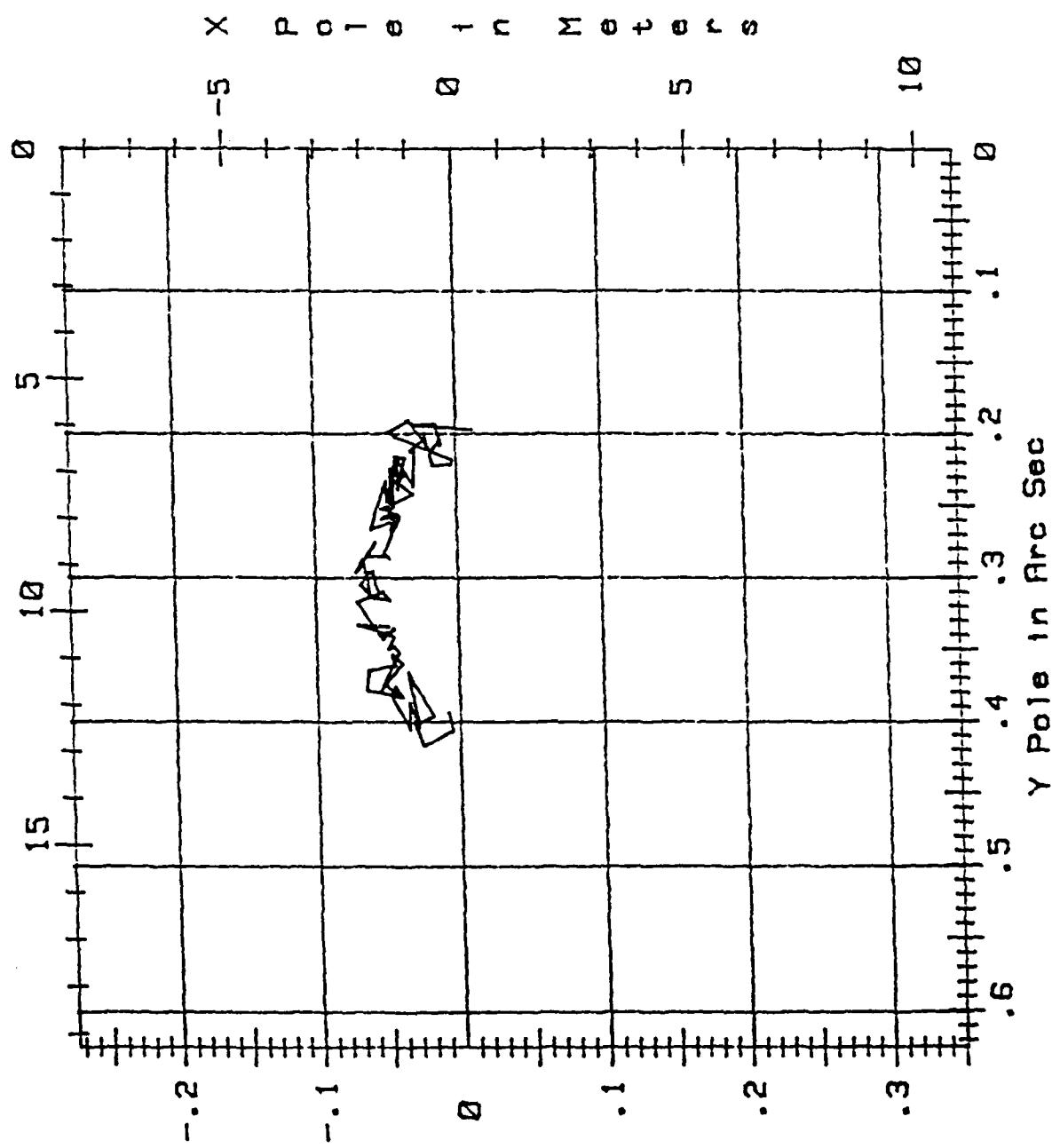


FIGURE 13:  
SATELLITE 30300  
DOPPLER POLAR MOTION  
RESULTS DURING  
1987

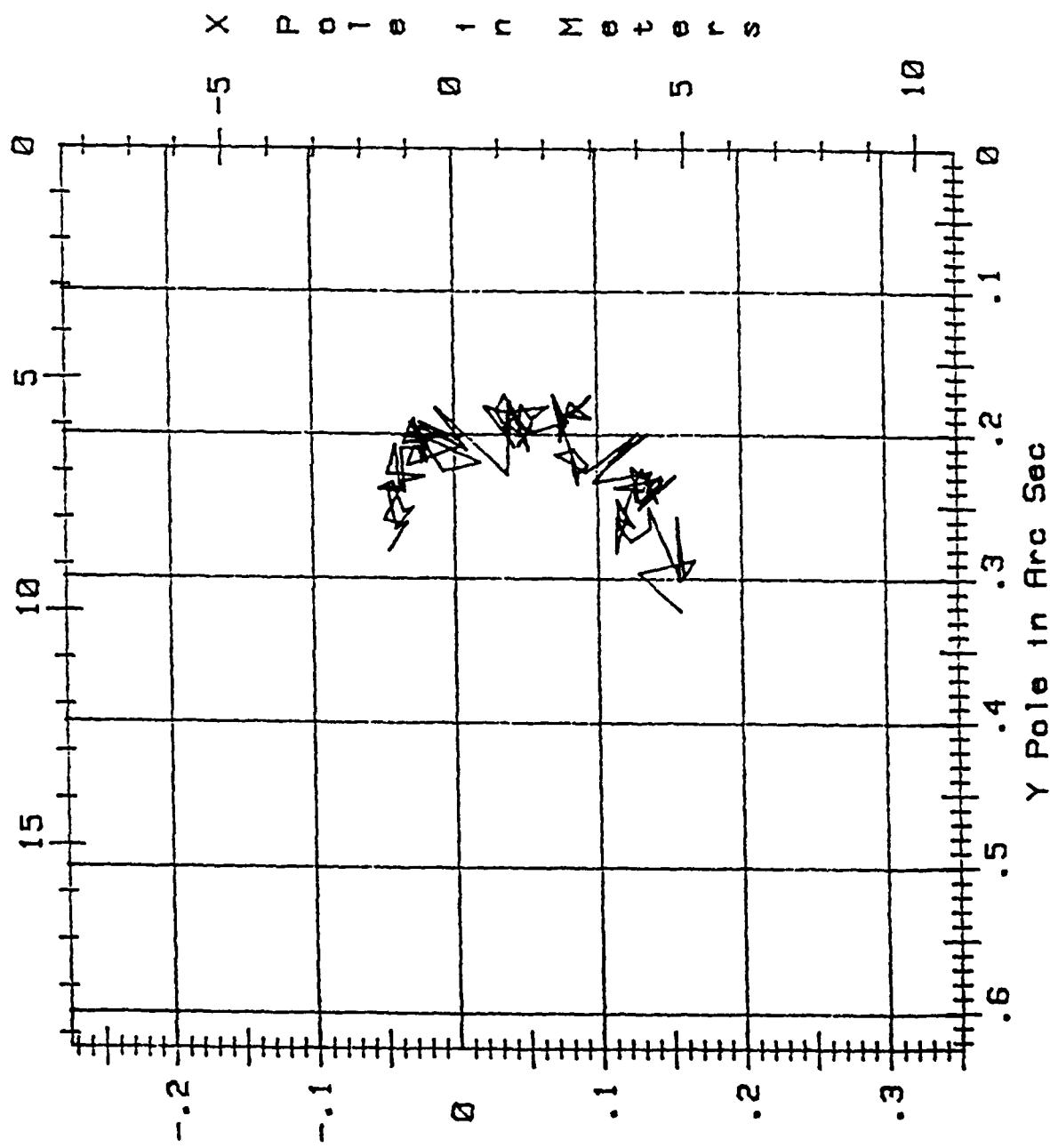


FIGURE 14:  
SATELLITE 30480  
DOPPLER POLAR MOTION  
RESULTS DURING  
1987

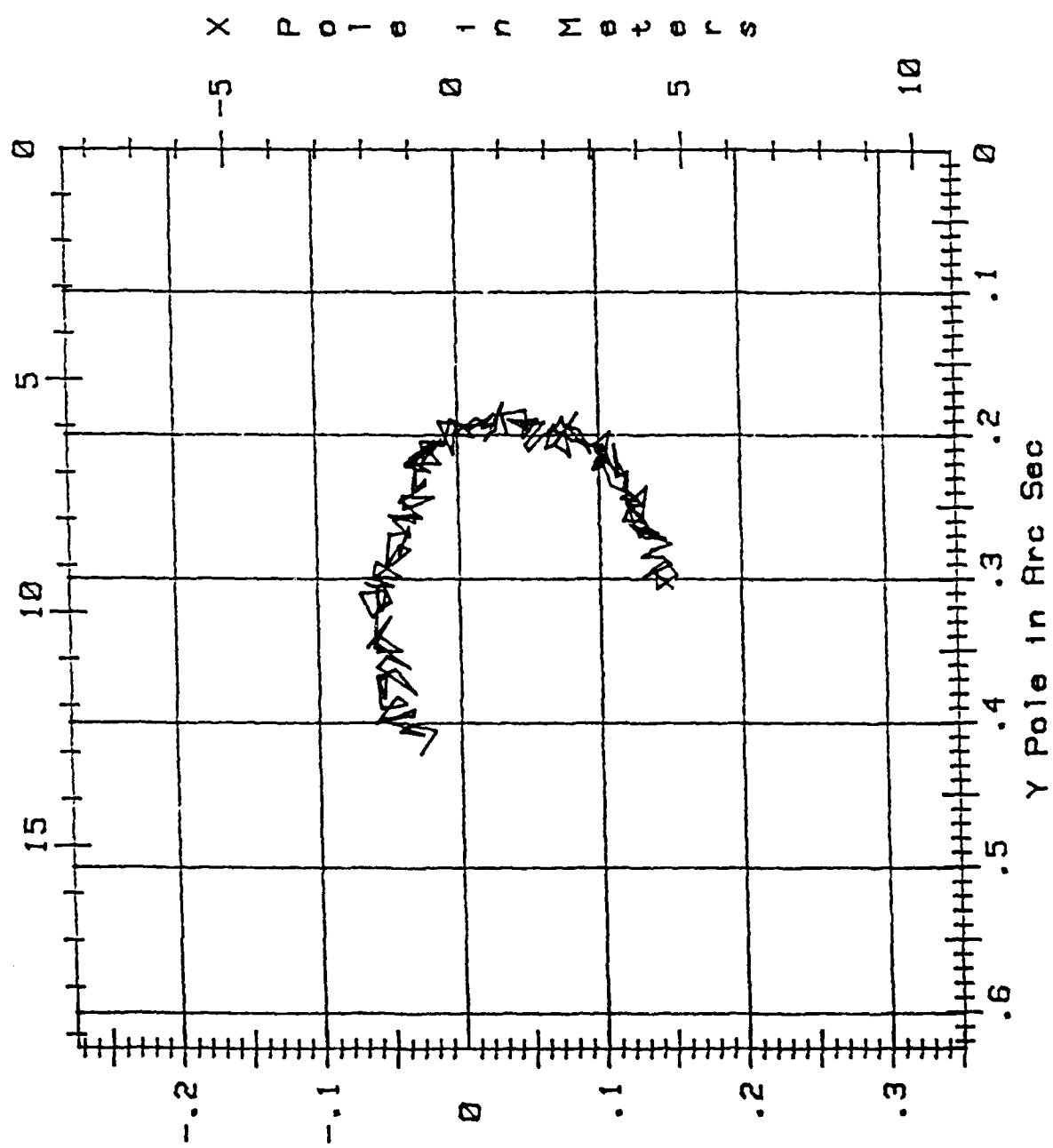


FIGURE 15:  
SATELLITE 30500  
DOPPLER POLAR MOTION  
RESULTS DURING  
1987

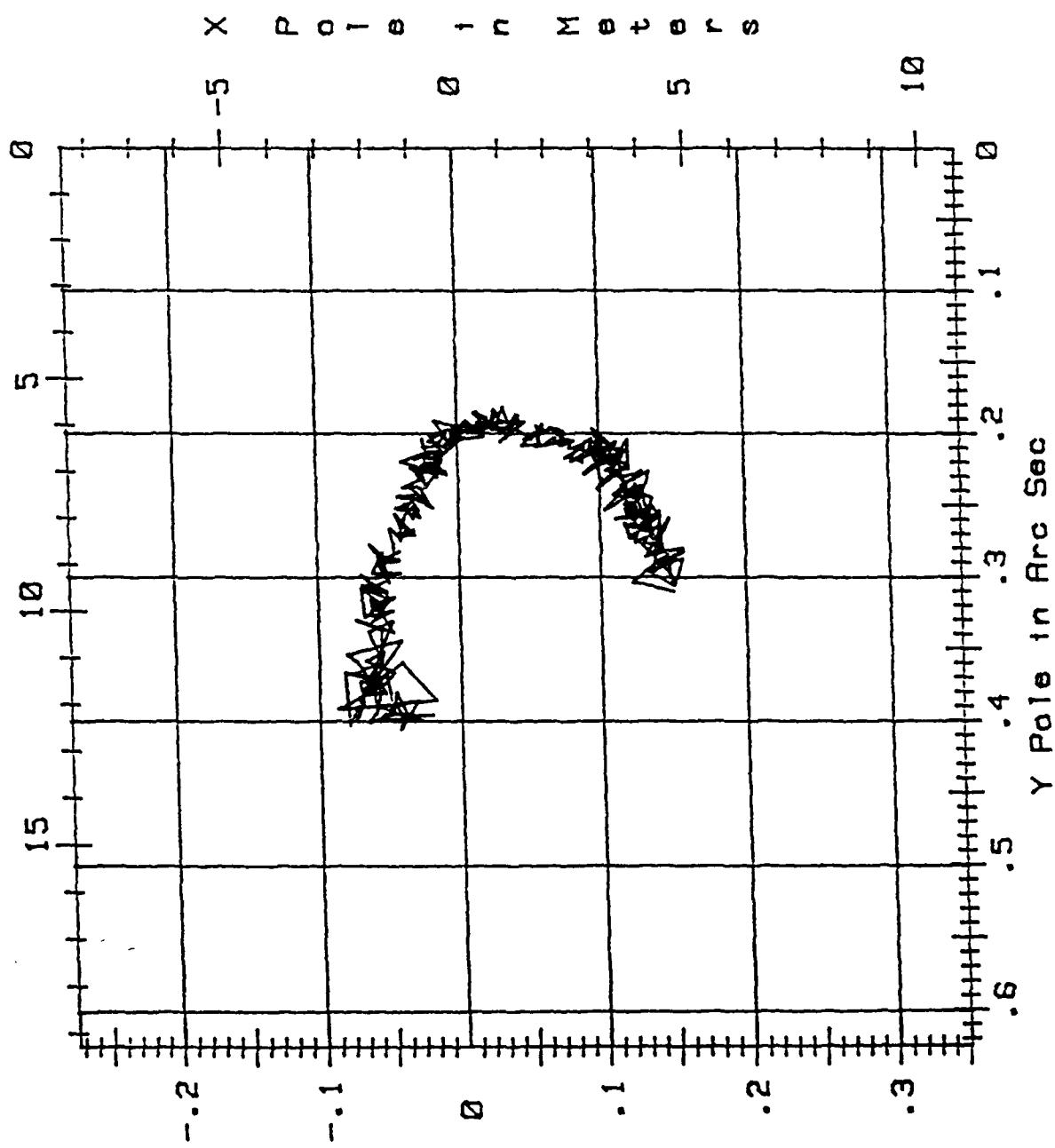


TABLE 7: COMPARISON OF DOPPLER AND BIH POLAR MOTION 1987

TRANSIT Satellite Number	X - Component		Y-Component		Number of Sp
	Mean*	RMS	Mean*	RMS	
30110	.0078	.0183	-.0094	.0197	182
30130	.0093	.0198	-.0138	.0241	153
30200	.0023	.0200	-.0098	.0196	153
30240	.0023	.0104	-.0130	.0170	89
30300	.0021	.0137	-.0119	.0190	129
30480	.0008	.0074	-.0065	.0102	151
30500	.0010	.0090	-.0068	.0119	364

\* Mean of Doppler - BIH

Units are in arc seconds.

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Stansell, T. A. (1978): The TRANSIT Navigation Satellite System, Magnavox, Torrance, California.

APPENDIX

DMAHTC POLE POSITION VALUES

1987

## OMAHTC POLE POSITION VALUES

UNITS: ARC SECONDS

YEAR	DAY	X POLE (ARCSECS)				Y POLE (ARCSECS)			
		30110	30130	30200	30240	30300	30480	30500	30550
87	1	145	187	120	150	150	244	307	310
87	2	149	154	157	122	286	294	322	304
87	3	131	128	140	139	146	317	296	284
87	4	131	115	128	151	151	285	296	306
87	5	138	131	115	140	133	293	307	297
87	6	138	131	131	167	157	328	287	287
87	7	137	171	177	159	154	268	297	305
87	8	137	171	177	145	142	284	298	289
87	9	150	159	159	155	157	294	287	282
87	10	150	159	185	130	136	263	258	293
87	11	138	131	147	157	154	268	299	283
97	12	138	131	117	150	151	294	298	289
87	13	137	171	117	135	140	263	275	282
87	14	146	159	159	144	144	278	301	299
87	15	134	157	157	136	136	261	290	296
87	16	134	129	129	129	129	296	290	283
87	17	123	163	123	123	143	275	251	282
87	18	123	163	129	140	140	276	265	286
87	19	152	122	107	135	135	263	258	276
87	20	152	122	118	113	150	258	285	268
87	21	136	140	122	129	142	298	275	280
87	22	136	140	129	129	140	256	279	276
87	23	159	176	129	125	135	242	265	263
87	24	140	147	155	130	130	258	285	286
87	25	130	141	113	113	140	290	275	277
87	26	130	141	146	113	136	257	267	284
87	27	149	164	127	112	148	298	279	284
87	28	159	176	127	129	131	275	264	271
87	29	140	147	155	125	135	263	266	278
87	30	124	126	127	113	150	278	245	254
87	31	149	164	112	112	146	288	272	283
87	32	149	164	112	125	136	259	267	263
87	33	159	176	155	131	140	233	264	284
87	34	123	130	126	120	122	291	257	271
87	35	133	162	126	113	142	297	258	254
87	36	098	117	117	138	113	232	272	263
87	37	115	184	119	119	137	271	282	263
87	38	108	195	118	118	124	245	267	273
87	39	123	130	130	131	132	260	224	256
87	40	155	141	094	126	121	249	268	263
87	41	174	174	127	121	117	232	254	247
87	42	108	115	115	118	119	273	224	266
87	43	133	162	117	118	119	215	233	249
87	44	133	162	126	126	125	244	240	264
87	45	133	133	117	138	143	273	245	247
87	46	115	184	119	119	119	259	269	264
87	47	106	106	108	126	110	242	270	248
87	48	143	144	117	128	122	260	252	256
87	49	134	134	130	133	131	279	251	252
							245	260	257
							243	243	243
							248	248	259
							229	229	249
							236	236	247
							243	243	264
							257	257	278

DMAHTC POLE POSITION VALUES  
UNITS: ARC SECONDS

YEAR	DAY	X POLE (ARCSECS)				Y POLE (ARCSECS)			
		30110	30130	30200	30240	30300	30480	30500	30550
87	53	.140	.119	.134	.135	.131	.134	.129	.125
87	54	.140	.119	.134	.127	.127	.240	.202	.255
87	55	.118	.125	.134	.115	.118	.238	.246	.238
87	56	.118	.100	.145	.115	.129	.233	.256	.238
87	57	.108	.145	.137	.119	.119	.233	.237	.231
87	58	.120	.123	.127	.142	.115	.104	.218	.229
87	59	.135	.127	.088	.126	.123	.123	.214	.214
87	60	.125	.130	.145	.154	.115	.115	.115	.115
87	61	.125	.138	.123	.117	.134	.134	.238	.237
87	62	.120	.123	.095	.128	.127	.127	.228	.250
87	63	.121	.115	.097	.108	.120	.109	.102	.112
87	64	.096	.110	.144	.140	.119	.129	.237	.241
87	65	.129	.144	.144	.140	.119	.115	.214	.214
87	66	.125	.130	.138	.138	.115	.113	.207	.191
87	67	.121	.115	.115	.111	.111	.117	.215	.215
87	68	.109	.141	.111	.097	.132	.108	.102	.102
87	69	.110	.116	.116	.107	.101	.096	.096	.096
87	70	.077	.099	.105	.107	.138	.112	.112	.112
87	71	.072	.105	.115	.097	.108	.108	.104	.104
87	72	.112	.120	.101	.114	.112	.112	.120	.120
87	73	.112	.115	.111	.112	.112	.112	.120	.120
87	74	.077	.077	.077	.077	.077	.077	.077	.077
87	75	.076	.099	.105	.107	.107	.107	.107	.107
87	76	.077	.099	.109	.115	.115	.115	.115	.115
87	77	.077	.120	.101	.114	.114	.114	.107	.107
87	78	.126	.138	.135	.135	.135	.135	.120	.120
87	79	.080	.126	.111	.117	.112	.112	.121	.121
87	80	.085	.121	.125	.107	.107	.107	.105	.105
87	81	.086	.108	.092	.092	.108	.108	.116	.116
87	82	.087	.097	.096	.096	.128	.096	.096	.096
87	83	.084	.093	.096	.096	.096	.096	.094	.094
87	84	.087	.092	.105	.135	.092	.096	.097	.097
87	85	.086	.119	.114	.077	.074	.104	.104	.104
87	86	.087	.060	.060	.060	.071	.071	.071	.071
87	87	.087	.071	.097	.097	.124	.124	.107	.107
87	88	.087	.093	.096	.096	.084	.084	.083	.083
87	89	.087	.092	.092	.105	.083	.096	.096	.096
87	90	.087	.092	.092	.074	.074	.093	.093	.093
87	91	.087	.066	.116	.116	.077	.093	.093	.093
87	92	.087	.071	.097	.097	.124	.084	.084	.084
87	93	.087	.094	.124	.124	.105	.103	.103	.103
87	94	.087	.092	.105	.074	.074	.102	.100	.100
87	95	.087	.094	.094	.094	.082	.082	.094	.094
87	96	.083	.121	.114	.077	.074	.104	.104	.104
87	97	.087	.111	.111	.060	.060	.060	.060	.060
87	98	.087	.127	.101	.124	.124	.107	.108	.108
87	99	.087	.097	.097	.092	.092	.086	.086	.086
87	100	.087	.094	.094	.094	.094	.094	.095	.095
87	101	.087	.094	.094	.094	.075	.075	.076	.076

AR	DAY	DMAHTC POLE POSITION VALUES											
		X POLE (ARCSECS)						Y POLE (ARCSECS)					
UNITS: ARC SECONDS													
		30200	30240	30300	30480	30500	30550	30130	30200	30240	30300	30480	30500
7	105	30110	30130	.086	.081	.078	.079	.195	.196	.154	.193	.217	.221
7	106	.111	.061	.090	.095	.090	.089	.217	.217	.187	.208	.208	.210
7	107	.079	.079	.071	.080	.069	.079	.185	.214	.189	.197	.206	.207
7	108	.094	.099	.087	.074	.080	.080	.180	.180	.204	.204	.209	.209
7	109	.086	.117	.087	.075	.068	.072	.206	.205	.178	.189	.198	.203
7	110	.111	.064	.099	.094	.099	.095	.180	.180	.171	.171	.195	.196
7	111	.094	.086	.084	.073	.073	.075	.178	.210	.189	.189	.203	.205
7	112	.083	.086	.087	.078	.069	.069	.179	.214	.207	.207	.205	.205
7	113	.086	.084	.087	.078	.078	.078	.204	.199	.177	.177	.208	.208
7	114	.115	.061	.064	.064	.066	.066	.195	.195	.194	.194	.206	.206
7	115	.116	.071	.087	.078	.070	.070	.204	.199	.185	.185	.201	.201
7	116	.117	.066	.058	.054	.085	.085	.195	.201	.194	.194	.196	.196
7	117	.120	.086	.061	.058	.060	.063	.204	.199	.173	.173	.198	.198
7	118	.121	.066	.066	.066	.080	.080	.195	.195	.191	.191	.209	.209
7	119	.122	.090	.078	.078	.069	.069	.195	.195	.191	.191	.207	.207
7	120	.123	.086	.079	.079	.053	.053	.188	.197	.173	.173	.196	.196
7	121	.124	.087	.076	.076	.054	.054	.181	.187	.182	.182	.206	.206
7	122	.125	.125	.048	.048	.048	.048	.181	.187	.182	.182	.209	.209
7	123	.126	.126	.061	.061	.045	.045	.181	.187	.184	.184	.207	.207
7	124	.127	.066	.064	.045	.062	.062	.181	.187	.182	.182	.208	.208
7	125	.128	.080	.073	.063	.047	.047	.181	.187	.182	.182	.208	.208
7	126	.129	.080	.069	.069	.055	.047	.181	.186	.185	.185	.207	.207
7	130	.131	.080	.061	.036	.066	.066	.181	.186	.185	.185	.206	.206
7	131	.132	.085	.067	.025	.047	.047	.190	.198	.180	.180	.197	.197
7	132	.133	.064	.061	.036	.037	.057	.042	.176	.183	.193	.193	.203
7	133	.134	.078	.045	.040	.040	.047	.037	.190	.198	.189	.189	.204
7	134	.135	.064	.061	.036	.036	.057	.042	.176	.183	.193	.193	.204
7	135	.136	.078	.045	.045	.037	.046	.037	.176	.172	.184	.184	.192
7	136	.137	.068	.037	.047	.039	.044	.036	.183	.234	.190	.190	.195
7	137	.138	.085	.067	.025	.039	.039	.039	.209	.170	.199	.199	.206
7	138	.139	.083	.032	.036	.036	.036	.034	.161	.161	.189	.189	.203
7	139	.140	.069	.097	.042	.039	.039	.034	.170	.181	.190	.190	.197
7	140	.141	.062	.064	.041	.038	.040	.040	.233	.182	.177	.177	.187
7	141	.142	.068	.037	.037	.039	.044	.035	.214	.163	.182	.182	.201
7	142	.143	.053	.065	.039	.039	.048	.030	.209	.156	.211	.211	.192
7	143	.144	.083	.032	.041	.041	.048	.048	.202	.195	.185	.185	.193
7	144	.145	.069	.054	.041	.038	.040	.040	.209	.226	.177	.177	.191
7	145	.146	.062	.064	.031	.035	.035	.024	.209	.226	.199	.199	.197
7	146	.147	.053	.065	.039	.052	.048	.030	.188	.186	.182	.182	.192
7	147	.148	.083	.032	.041	.041	.048	.048	.202	.195	.186	.186	.193
7	148	.149	.069	.054	.041	.038	.040	.040	.200	.167	.201	.201	.196
7	149	.150	.098	.044	.042	.050	.039	.039	.220	.220	.178	.178	.196
7	150	.151	.062	.013	.034	.034	.024	.024	.183	.226	.192	.192	.183
7	151	.152	.072	.023	.037	.034	.026	.026	.183	.169	.203	.203	.193
7	152	.153	.053	.065	.037	.019	.029	.029	.202	.195	.184	.184	.193

YEAR	DAY	DRAHTIC POLE POSITION VALUES													
		X POLE (ARCSECS)						Y POLE (ARCSECS)							
UNITS: ARC SECONDS		30110	30130	30200	30240	30300	30480	30500	30110	30130	30200	30240	30300	30480	30500
87	157	.043	.022	.041	.052	.030	.019	.023	.181	.237	.191	.198	.183	.194	
87	158	.043	.022	.027	.027	.031	.031	.025	.193	.218	.167	.192	.192	.199	
87	159	.052	.058	.042	.042	.025	.029	.029	.021	.157	.195	.195	.195	.195	
87	160	.052	.058	.039	.017	.021	.021	.021	.235	.212	.202	.185	.185	.196	
87	161	.036	.031	.035	.035	.026	.012	.012	.190	.193	.152	.181	.194	.186	
87	162	.036	.031	.012	.042	.042	.021	.018	.194	.201	.202	.181	.194	.186	
87	163	.053	.009	.009	.007	.007	.018	.014	.194	.193	.172	.178	.197	.202	
87	164	.053	.009	.007	.021	.021	.014	.014	.194	.201	.202	.188	.188	.185	
87	165	.029	.023	.038	.038	.013	.005	.005	.184	.185	.208	.228	.228	.193	
87	170	.029	.023	.005	.005	.037	.003	.003	.182	.183	.181	.181	.181	.195	
87	171	.036	.020	.020	.020	.004	.014	.014	.198	.165	.182	.182	.182	.193	
87	172	.024	.016	.004	.004	.013	.003	.003	.014	.014	.193	.172	.172	.196	
87	173	.033	.040	.007	.021	.021	.014	.014	.194	.194	.193	.192	.192	.193	
87	174	.020	.029	.023	.023	.013	.029	.029	.184	.185	.188	.188	.188	.194	
87	175	.031	.031	.012	.012	.013	.013	.013	.005	.005	.208	.228	.228	.194	
87	176	.048	.050	.009	.009	.017	.003	.003	.182	.183	.181	.181	.181	.195	
87	177	.023	.007	.007	.025	.013	.003	.003	.014	.014	.216	.193	.182	.193	
87	178	.023	.007	.007	.014	.014	.005	.005	.005	.005	.184	.185	.182	.196	
87	179	.008	.021	.002	.002	.012	.012	.012	.007	.007	.207	.217	.211	.202	
87	180	.008	.021	.031	.031	.009	.019	.019	.019	.019	.183	.189	.193	.204	
87	181	.030	.030	.004	.004	.002	.002	.002	.003	.003	.203	.189	.192	.193	
87	182	.017	.007	.007	.025	.005	.005	.005	.005	.005	.216	.193	.191	.194	
87	183	.023	.007	.007	.014	.014	.005	.005	.005	.005	.192	.185	.182	.198	
87	184	.017	.018	.007	.007	.002	.002	.002	.016	.016	.192	.223	.203	.202	
87	185	.030	.030	.018	.018	.006	.006	.006	.017	.017	.207	.217	.211	.214	
87	186	.002	.008	.018	.018	.018	.018	.018	.021	.021	.216	.237	.200	.199	
87	187	.013	.013	.008	.008	.002	.002	.002	.003	.003	.203	.189	.192	.191	
87	188	.000	.010	.033	.033	.012	.012	.012	.009	.009	.197	.171	.201	.209	
87	189	.013	.011	.031	.031	.014	.014	.014	.014	.014	.206	.233	.197	.198	
87	190	.013	.011	.007	.007	.010	.010	.010	.021	.021	.188	.183	.219	.210	
87	191	.035	.035	.003	.003	.012	.012	.012	.021	.021	.216	.210	.200	.204	
87	192	.008	.018	.014	.014	.030	.014	.014	.009	.009	.197	.171	.190	.192	
87	193	.018	.014	.028	.018	.033	.033	.033	.021	.021	.192	.194	.190	.192	
87	194	.030	.028	.011	.011	.010	.010	.010	.013	.013	.208	.224	.226	.206	
87	195	.013	.014	.007	.007	.030	.023	.023	.021	.021	.185	.201	.208	.197	
87	196	.009	.035	.011	.011	.010	.010	.010	.006	.006	.216	.212	.226	.210	
87	197	.018	.014	.010	.010	.012	.025	.025	.000	.000	.198	.181	.213	.204	
87	198	.018	.014	.032	.018	.033	.033	.033	.018	.018	.196	.197	.191	.211	
87	199	.030	.028	.011	.011	.010	.010	.010	.027	.027	.192	.197	.208	.205	
87	200	.013	.014	.009	.009	.020	.023	.023	.013	.013	.208	.224	.228	.206	
87	201	.004	.008	.010	.010	.011	.011	.011	.013	.013	.198	.181	.209	.205	
87	202	.004	.008	.036	.036	.033	.028	.028	.020	.020	.196	.191	.191	.211	
87	203	.001	.010	.010	.010	.048	.048	.048	.029	.029	.190	.208	.206	.212	
87	204	.011	.011	.011	.011	.011	.011	.011	.016	.016	.225	.182	.200	.213	
87	205	.021	.004	.017	.017	.025	.025	.025	.025	.025	.210	.210	.201	.227	

YEAR	DAY	DMAHTC POLE POSITION VALUES											
		X POLE (ARCSECS)						Y POLE (ARCSECS)					
UNITS: ARC SECONDS		30110			30130			30200			30300		
		30240	30300	30480	30500	30550	30600	30720	30780	30840	30980	310500	
		.004	.012	.022	.033	.043	.053	.063	.073	.083	.093	.220	.213
87	209	.018	.029	.055	.017	.022	.015	.015	.015	.015	.015	.215	.215
87	210	.024	.006	.025	.025	.024	.024	.024	.024	.024	.024	.226	.226
87	211	.024	.024	.022	.022	.037	.018	.018	.018	.018	.018	.227	.227
87	212	.013	.049	.049	.032	.037	.040	.040	.040	.040	.040	.220	.220
87	214	.001	.049	.055	.032	.020	.023	.023	.023	.023	.023	.213	.213
87	215	.003	.027	.027	.029	.029	.029	.029	.029	.029	.029	.228	.228
87	216	.023	.016	.029	.029	.026	.024	.024	.024	.024	.024	.226	.226
87	217	.023	.002	.019	.019	.019	.034	.034	.034	.034	.034	.224	.224
87	218	.023	.044	.044	.030	.031	.025	.025	.025	.025	.025	.217	.230
87	219	.046	.018	.038	.038	.030	.011	.011	.011	.011	.011	.210	.222
87	220	.027	.001	.041	.041	.035	.016	.016	.016	.016	.016	.217	.218
87	221	.027	.035	.035	.035	.030	.015	.015	.015	.015	.015	.240	.227
87	222	.023	.029	.041	.041	.030	.024	.024	.024	.024	.024	.226	.237
87	223	.038	.026	.039	.039	.030	.030	.025	.025	.025	.025	.237	.229
87	224	.038	.011	.036	.036	.030	.028	.028	.028	.028	.028	.234	.222
87	225	.012	.037	.042	.042	.033	.027	.027	.027	.027	.027	.234	.230
87	226	.061	.018	.017	.043	.033	.027	.027	.027	.027	.027	.241	.227
87	227	.025	.017	.017	.043	.047	.030	.023	.023	.023	.023	.237	.237
87	228	.010	.018	.040	.046	.023	.030	.030	.030	.030	.030	.231	.223
87	229	.012	.037	.022	.022	.024	.024	.025	.025	.025	.025	.224	.226
87	230	.034	.010	.008	.040	.040	.036	.036	.036	.036	.036	.217	.218
87	231	.025	.019	.019	.044	.038	.039	.039	.039	.039	.039	.240	.230
87	232	.025	.017	.017	.047	.047	.041	.026	.026	.026	.026	.234	.231
87	233	.045	.045	.036	.036	.037	.021	.021	.021	.021	.021	.229	.231
87	234	.033	.010	.010	.008	.040	.040	.036	.036	.036	.036	.235	.238
87	235	.034	.029	.029	.046	.046	.036	.036	.036	.036	.036	.215	.237
87	236	.034	.017	.067	.044	.038	.018	.018	.018	.018	.018	.227	.238
87	237	.029	.012	.012	.053	.053	.024	.024	.024	.024	.024	.239	.248
87	238	.029	.015	.045	.045	.044	.039	.018	.018	.018	.018	.232	.237
87	239	.016	.022	.058	.053	.044	.044	.036	.036	.036	.036	.235	.242
87	240	.034	.029	.047	.046	.038	.044	.044	.044	.044	.044	.244	.245
87	241	.031	.040	.031	.036	.036	.042	.042	.042	.042	.042	.247	.238
87	242	.026	.031	.003	.044	.050	.026	.026	.026	.026	.026	.231	.231
87	243	.027	.041	.051	.052	.030	.027	.027	.027	.027	.027	.235	.237
87	244	.027	.058	.053	.053	.045	.027	.027	.027	.027	.027	.248	.244
87	245	.031	.040	.047	.046	.038	.044	.044	.044	.044	.044	.254	.244
87	246	.026	.012	.012	.041	.041	.049	.028	.028	.028	.028	.256	.246
87	247	.023	.043	.017	.017	.015	.039	.018	.018	.018	.018	.251	.252
87	248	.028	.051	.051	.052	.041	.041	.041	.041	.041	.041	.256	.244
87	249	.038	.043	.046	.046	.038	.038	.038	.038	.038	.038	.237	.253
87	250	.038	.046	.031	.047	.047	.047	.029	.029	.029	.029	.242	.246
87	251	.023	.043	.027	.027	.027	.032	.032	.032	.032	.032	.257	.258
87	252	.023	.050	.046	.046	.046	.046	.031	.031	.031	.031	.260	.256
87	253	.028	.050	.051	.052	.041	.041	.033	.033	.033	.033	.251	.252
87	254	.027	.035	.048	.048	.035	.035	.038	.038	.038	.038	.255	.255
87	255	.026	.028	.034	.034	.034	.034	.041	.041	.041	.041	.261	.256
87	256	.026	.027	.028	.028	.028	.028	.041	.041	.041	.041	.264	.268
87	257	.026	.027	.028	.028	.028	.028	.046	.046	.046	.046	.280	.266

YEAR	DAY	OMAHTC POLE POSITION VALUES											
		X POLE (ARCSECS)						Y POLE (ARCSECS)					
UNITS: ARC SECONDS													
		30110	30130	30200	30240	30300	30480	30500	30110	30130	30200	30240	30300
87	261	.014	.015	.015	.043	.043	.043	.032	.032	.032	.291	.260	.284
87	262	.014	.015	.059	.060	.037	.042	.042	.272	.264	.248	.266	.267
87	263	.031	.046	.028	.049	.050	.041	.041	.042	.242	.265	.233	.263
87	264	.041	.045	.070	.051	.035	.048	.042	.037	.037	.281	.286	.275
87	265	.077	.087	.087	.048	.052	.047	.047	.041	.041	.284	.259	.268
87	266	.017	.034	.002	.040	.042	.049	.049	.047	.047	.288	.277	.271
87	268	.017	.034	.002	.040	.042	.049	.049	.047	.047	.277	.277	.266
87	269	.041	.045	.028	.051	.035	.048	.042	.037	.037	.286	.280	.287
87	270	.041	.045	.071	.078	.051	.052	.052	.048	.048	.286	.283	.280
87	271	.049	.048	.025	.048	.061	.042	.042	.041	.041	.292	.288	.284
87	272	.049	.048	.035	.063	.042	.053	.053	.047	.047	.296	.295	.290
87	273	.066	.022	.022	.057	.061	.053	.053	.053	.053	.301	.285	.289
87	274	.029	.053	.056	.052	.059	.059	.059	.053	.053	.296	.295	.290
87	275	.051	.033	.035	.035	.063	.042	.053	.053	.053	.270	.286	.288
87	276	.049	.048	.048	.048	.066	.064	.064	.064	.064	.277	.277	.289
87	277	.066	.022	.022	.042	.057	.061	.053	.053	.053	.298	.275	.293
87	278	.029	.053	.054	.054	.067	.060	.060	.060	.060	.300	.295	.304
87	279	.050	.052	.043	.061	.060	.060	.060	.050	.050	.290	.297	.290
87	280	.028	.054	.052	.071	.065	.057	.057	.057	.057	.274	.285	.287
87	281	.049	.048	.048	.050	.066	.047	.055	.055	.055	.319	.273	.277
87	282	.049	.048	.048	.050	.066	.061	.061	.061	.061	.296	.298	.293
87	283	.050	.052	.052	.052	.067	.055	.055	.055	.055	.301	.285	.300
87	284	.050	.052	.043	.061	.061	.060	.060	.060	.060	.309	.290	.296
87	285	.050	.058	.058	.058	.068	.067	.067	.067	.067	.301	.337	.305
87	286	.050	.058	.033	.068	.068	.067	.067	.067	.067	.326	.288	.305
87	287	.040	.073	.073	.070	.062	.052	.052	.052	.052	.301	.285	.300
87	288	.040	.073	.073	.070	.062	.062	.062	.062	.062	.290	.296	.297
87	289	.069	.057	.057	.055	.059	.055	.055	.055	.055	.323	.297	.299
87	290	.069	.057	.055	.055	.059	.055	.055	.055	.055	.301	.337	.303
87	291	.061	.056	.056	.058	.060	.060	.060	.060	.060	.327	.296	.304
87	292	.050	.056	.056	.058	.060	.060	.060	.060	.060	.314	.296	.311
87	293	.051	.063	.019	.055	.055	.055	.055	.055	.055	.314	.314	.316
87	294	.051	.063	.019	.055	.055	.055	.055	.055	.055	.310	.312	.310
87	295	.061	.069	.069	.068	.058	.068	.068	.068	.068	.307	.314	.310
87	296	.061	.069	.068	.068	.068	.068	.068	.068	.068	.336	.321	.308
87	297	.068	.042	.050	.058	.050	.050	.050	.050	.050	.319	.314	.311
87	298	.068	.042	.050	.058	.050	.050	.050	.050	.050	.316	.286	.327
87	299	.068	.062	.062	.062	.071	.071	.071	.071	.071	.316	.296	.327
87	300	.039	.063	.062	.062	.047	.047	.047	.047	.047	.310	.327	.316
87	301	.071	.071	.071	.071	.071	.071	.071	.071	.071	.310	.315	.316
87	302	.071	.071	.065	.053	.053	.053	.053	.053	.053	.333	.315	.308
87	303	.076	.062	.062	.062	.071	.071	.071	.071	.071	.339	.317	.298
87	304	.076	.062	.062	.062	.073	.073	.073	.073	.073	.337	.313	.318
87	305	.050	.050	.050	.050	.062	.062	.062	.062	.062	.309	.343	.348
87	306	.055	.052	.052	.052	.052	.052	.052	.052	.052	.320	.313	.331
87	307	.068	.043	.043	.043	.054	.054	.054	.054	.054	.346	.335	.337
87	308	.068	.043	.043	.043	.054	.054	.054	.054	.054	.336	.348	.313
87	309												

DMAHIC POLE POSITION VALUES  
UNITS: ARC SECONDS

YEAR	DAY	X POLE (ARCSECS)				Y POLE (ARCSECS)			
		30110	30130	30200	30240	30300	30480	30500	30540
87	313	.056	.021	.047	.049	.066	.056	.057	.054
87	314	.056	.021	.055	.071	.059	.065	.066	.064
87	315	.087	.052	.042	.045	.043	.048	.048	.047
87	316	.087	.052	.042	.045	.041	.050	.050	.049
87	317	.065	.057	.057	.064	.059	.064	.064	.063
87	318	.064	.029	.035	.045	.057	.074	.074	.073
87	319	.064	.032	.032	.045	.042	.081	.081	.080
87	320	.065	.044	.044	.042	.036	.068	.068	.067
87	321	.074	.044	.065	.042	.047	.042	.042	.041
87	322	.074	.044	.065	.042	.040	.047	.047	.046
87	323	.070	.041	.041	.047	.032	.068	.068	.067
87	324	.064	.029	.038	.055	.052	.018	.018	.017
87	325	.070	.066	.066	.045	.059	.088	.088	.087
87	326	.039	.053	.053	.078	.040	.052	.052	.051
87	327	.060	.078	.078	.040	.059	.052	.052	.051
87	328	.070	.041	.041	.044	.047	.047	.047	.046
87	329	.061	.060	.060	.065	.070	.055	.055	.054
87	330	.070	.066	.066	.069	.069	.059	.059	.058
87	331	.060	.078	.078	.078	.063	.076	.076	.075
87	332	.060	.078	.078	.078	.063	.060	.060	.060
87	333	.061	.060	.060	.065	.065	.063	.063	.062
87	334	.061	.060	.060	.065	.065	.072	.072	.071
87	335	.046	.046	.046	.046	.042	.069	.069	.068
87	336	.046	.046	.046	.046	.040	.053	.075	.075
87	337	.046	.054	.054	.054	.052	.064	.064	.063
87	338	.046	.054	.054	.054	.052	.059	.059	.058
87	339	.062	.046	.046	.046	.052	.074	.074	.073
87	340	.056	.067	.067	.067	.059	.063	.063	.062
87	341	.039	.045	.045	.045	.039	.057	.057	.056
87	342	.053	.030	.030	.042	.042	.053	.053	.052
87	343	.062	.046	.046	.046	.050	.061	.061	.060
87	344	.062	.046	.046	.046	.052	.062	.062	.061
87	345	.031	.040	.030	.041	.030	.054	.054	.053
87	346	.048	.070	.070	.060	.060	.069	.069	.068
87	347	.026	.037	.037	.037	.037	.053	.053	.052
87	348	.066	.064	.054	.035	.054	.062	.062	.061
87	349	.015	.049	.049	.049	.000	.036	.036	.035
87	350	.031	.040	.040	.041	.035	.042	.042	.041
87	351	.051	.040	.040	.040	.041	.047	.047	.046
87	352	.026	.029	.029	.029	.029	.047	.047	.046
87	353	.015	.038	.038	.038	.035	.036	.036	.035
87	354	.024	.049	.049	.049	.000	.032	.032	.031
87	355	.031	.040	.040	.040	.041	.047	.047	.046
87	356	.051	.040	.040	.040	.043	.019	.019	.018
87	357	.026	.037	.037	.037	.026	.029	.029	.028
87	358	.015	.038	.038	.038	.009	.032	.032	.031
87	359	.024	.049	.049	.049	.000	.036	.036	.035
87	360	.031	.040	.040	.040	.025	.056	.056	.055
87	361	.051	.040	.040	.040	.043	.019	.019	.018
87	362	.010	.044	.044	.044	.003	.005	.005	.004

OMAHTC POLE POSITION VALUES		Y POLE (ARCSECS)	
UNITS: ARC SECONDS			
YEAR	DAY	X POLE (ARCSECS)	Y POLE (ARCSECS)
87	365	30110 30130 30150 30170 30190 30210 30230 30250 30270 30290 30310 30330 30350 30370 30390 30410 30430 30450 30470 30490 30510 30530 30550	.029 30480 30500 30520 30540 30560 30580 30600 30620 30640 30660 30680 30700 30720 30740 30760 30780 30800 30820 30840 30860 30880 30900 30920

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